

What is claimed is:

1 1. A system for assigning time slots in a packet communication
2 system comprising a network-side apparatus and a plurality
3 of terminal-side apparatuses connected to the network-side
4 apparatus through a shared transmission medium, the
5 network-side apparatus being adapted to assign time slots to
6 the terminal-side apparatuses, each of the terminal-side
7 apparatuses being adapted to transfer one or more packets over
8 the shared transmission medium by using the time slots assigned
9 thereto,

10 the terminal-side apparatus comprising:

11 buffering means for use in storing the packets to be
12 transferred; and

13 notification means connected to said buffering means and
14 the network-side apparatus, said notification means being
15 adapted to supply, to the network-side apparatus, information
16 indicative of the number of the packets stored in said buffering
17 means as packets information;

18 the network-side apparatus comprising:

19 control means connected to each of the terminal-side
20 apparatuses, said control means being adapted to assign, in
21 response to the packets information supplied from each of the
22 terminal-side apparatuses, time slots to the terminal-side
23 apparatuses in accordance with a predetermined fairness
24 criteria, the time slots being assigned as primarily assigned
25 time slots, and

26 when one or more leftover time slots are present in at
27 least one terminal-side apparatuses after the assignment of
28 the primarily assigned time slots, then said control means:
29 designating the terminal-side apparatus(es) with such
30 leftover time slot(s) as non-available terminal-side
31 apparatus(es) for reassignment and the remaining
32 terminal-side apparatus(es) as available terminal-side
33 apparatus(es) for reassignment, and
34 reassigning the leftover time slot(s) to the available
35 terminal-side apparatus(es) for reassignment.

1 2. A system as claimed in Claim 1, wherein said control means
2 compares the number of the primarily assigned time slots with
3 the number of the packets stored, and designates the number
4 of the primarily assigned time slots as the final number of
5 the time slots assigned to the terminal-side apparatuses when
6 the number of the primarily assigned time slots is smaller
7 than the number of the packets stored for all terminal-side
8 apparatuses.

1 3. A system as claimed in Claim 1, wherein the fairness
2 criteria is for assigning the time slots equally to the
3 terminal-side apparatuses.

1 4. A system as claimed in Claim 1, wherein the fairness
2 criteria is for assigning the time slots to the terminal-side

3 apparatuses in proportion to the sum of guaranteed minimum
4 bandwidths for connections in the terminal-side apparatuses.

1 5. A system as claimed in Claim 1, wherein the fairness
2 criteria is for assigning the time slots to the terminal-side
3 apparatuses in proportion to the sum of maximum bandwidths
4 for connections in the terminal-side apparatuses.

1 6. A system as claimed in Claim 1, wherein the fairness
2 criteria is for assigning the time slots to the terminal-side
3 apparatuses in proportion to the difference between the sum
4 of maximum bandwidths and the sum of guaranteed minimum
5 bandwidths for connections in the terminal-side apparatuses.

1 7. A system as claimed in Claim 1, wherein the fairness
2 criteria is for assigning the time slots to the terminal-side
3 apparatuses in proportion to the number of connections in the
4 terminal-side apparatuses.

1 8. A system as claimed in Claim 1, wherein the fairness
2 criteria is for assigning a part of total time slots equally
3 to the terminal-side apparatuses and then assigning the
4 remaining time slots in proportion to the sum of guaranteed
5 minimum bandwidths for connections in the terminal-side
6 apparatuses.

1 9. A system as claimed in Claim 1, wherein the fairness
2 criteria is for assigning a part of total time slots equally
3 to the terminal-side apparatuses and then assigning the
4 remaining time slots in proportion to the sum of maximum
5 bandwidths for connections in the terminal-side apparatuses.

1 10. A system as claimed in Claim 1, wherein the fairness
2 criteria is for assigning a part of total time slots equally
3 to the terminal-side apparatuses and then assigning the
4 remaining time slots in proportion to the difference between
5 the sum of maximum bandwidths and the sum of guaranteed minimum
6 bandwidths for connections in the terminal-side apparatuses.

1 11. A system as claimed in Claim 1, wherein the fairness
2 criteria is for assigning a part of total time slots equally
3 to the terminal-side apparatuses and then assigning the
4 remaining time slots in proportion to the number of connections
5 in the terminal-side apparatuses.

1 12. A system as claimed in Claim 1, wherein said control means
2 controls, on an equivalent assignment, reassignment of the
3 leftover time slots to the available terminal-side
4 apparatus(es) for reassignment.

1 13. A system as claimed in Claim 1, wherein said control means
2 controls reassignment of the leftover time slots to the
3 available terminal-side apparatus(es) for reassignment, such

4 that the value obtained by subtracting the number of the
5 primarily assigned time slots from the number of the packets
6 to be transferred becomes minimum in the available
7 terminal-side apparatus(es) for reassignment.

1 14. A system as claimed in Claim 1, wherein said control means
2 controls reassignment of the leftover time slots to the
3 available terminal-side apparatus(es) for reassignment in
4 proportion to the number of the packets to be transferred.

1 15. A system as claimed in Claim 1, wherein the packet is
2 a cell to be used in an asynchronous transfer mode.

1 16. A system for assigning time slots in a packet communication
2 system comprising a network-side apparatus and a plurality
3 of terminal-side apparatuses connected to the network-side
4 apparatus through a shared transmission medium, the
5 network-side apparatus being adapted to assign time slots to
6 the terminal-side apparatuses, each of the terminal-side
7 apparatuses being adapted to transfer one or more packets over
8 the shared transmission medium by using the time slots assigned
9 thereto,

10 the terminal-side apparatus comprising:

11 buffering means for use in storing the packets to be
12 transferred; and

13 notification means connected to said buffering means and
14 the network-side apparatus, said notification means being

15 adapted to supply, to the network-side apparatus, information
16 indicative of the number of the packets stored in said buffering
17 means as packets information;

18 the network-side apparatus comprising:

19 control means connected to each of the terminal-side
20 apparatuses, said control means being adapted to assign, in
21 response to the packets information supplied from each of the
22 terminal-side apparatuses time slots to the terminal-side
23 apparatuses in accordance with a predetermined fairness
24 criteria, the time slots being assigned as primarily assigned
25 time slots, and

26 when one or more leftover time slots are present in at
27 least one terminal-side apparatuses after the assignment of
28 the primarily assigned time slots, then said control means:

29 designating the terminal-side apparatus(es) with such
30 leftover time slot(s) as non-available terminal-side
31 apparatus(es) for reassignment and the remaining
32 terminal-side apparatus(es) as available terminal-side
33 apparatus(es) for reassignment,

34 reassigning the leftover time slot(s) to the available
35 terminal-side apparatus(es) for reassignment,

36 designating the sum of the differences between the number
37 of the primarily assigned time slots to the non-available
38 terminal-side apparatus(es) and the number of the packets
39 stored, as the number of the leftover time slots to be
40 reassigned,

41 making the number of the primarily assigned time slots
42 to the non-available terminal-side apparatus(es) for
43 reassignment, be identical to the number of the packets stored,
44 reassigning the leftover time slots to the available
45 terminal-side apparatus(es) such that the number of the time
46 slots to the available terminal-side apparatus(es) does not
47 exceed the number of the packets stored, and
48 if the number of the time slots assigned becomes equal
49 to the number of the packets stored for all available
50 terminal-side apparatuses and at least one leftover time slot
51 remains unassigned,
52 said control means:
53 assigning the remaining time slot(s) to all of the
54 terminal-side apparatuses in accordance with the fairness
55 criteria, and
56 using the sum of the primarily assigned time slots and
57 the number of the leftover time slots reassigned, as a final
58 number of the time slots assigned to the corresponding
59 terminal-side apparatus.

1 17. A network-side apparatus connected to a plurality of
2 terminal-side apparatuses through a shared transmission
3 medium in a packet communication system, the network-side
4 apparatus being adapted to assign time slots to the
5 terminal-side apparatuses, each of the terminal-side
6 apparatuses having a buffer and being adapted to transfer one
7 or more packets over the shared transmission medium by using

8 the time slots assigned thereto, the network-side apparatus
9 comprising:

10 fairness assignment means connected to the terminal-side
11 apparatuses, said fairness assignment means being adapted to
12 assign time slots to the terminal-side apparatuses in
13 accordance with a predetermined fairness criteria, in response
14 to information indicative of the number of the packets stored
15 in the buffer; and

16 reassignment control means for use in, when one or more
17 leftover time slots are present in at least one terminal-side
18 apparatuses after the assignment of the primarily assigned
19 time slots, designating the terminal-side apparatus(es) with
20 such leftover time slot(s) as non-available terminal-side
21 apparatus(es) for reassignment and the remaining
22 terminal-side apparatus(es) as available terminal-side
23 apparatus(es) for reassignment, to control reassignment of
24 the leftover time slot(s) to the available terminal-side
25 apparatus(es) for reassignment.

1 18. A network-side apparatus as claimed in Claim 17, wherein
2 said fairness assignment means comprises:

3 an assignment information management table for managing,
4 for each of the terminal-side apparatuses, packets information
5 corresponding to information indicative of the number of the
6 packets stored in the terminal-side apparatus and supplied
7 from the terminal-side apparatus, assigned time slots
8 information corresponding to information indicative of the

9 number of time slots assigned to the terminal-side apparatus,
10 and identifier information indicating whether each of the
11 terminal-side apparatus is available for reassignment or not;
12 and

13 a fairness guarantee assignment circuit for assigning
14 the time slots to all or some of the terminal-side apparatuses
15 in accordance with the fairness criteria at the timing when
16 it is necessary to change assignment of the time slots, to
17 write the number of the time slots assigned to the terminal-side
18 apparatuses into the assignment information management table.

1 19. A network-side apparatus as claimed in Claim 17, wherein
2 the fairness criteria is for assigning the time slots equally
3 to the terminal-side apparatuses.

1 20. A network-side apparatus as claimed in Claim 17, wherein
2 the fairness criteria is for assigning the time slots to the
3 terminal-side apparatuses in proportion to the sum of
4 guaranteed minimum bandwidths for connections in the
5 terminal-side apparatuses.

1 21. A network-side apparatus as claimed in Claim 17, wherein
2 the fairness criteria is for assigning the time slots to the
3 terminal-side apparatuses in proportion to the sum of maximum
4 bandwidths for connections in the terminal-side apparatuses.

1 22. A network-side apparatus as claimed in Claim 17, wherein
2 the fairness criteria is for assigning the time slots to the
3 terminal-side apparatuses in proportion to the difference
4 between the sum of maximum bandwidths and the sum of guaranteed
5 minimum bandwidths for connections in the terminal-side
6 apparatuses.

1 23. A network-side apparatus as claimed in Claim 17, wherein
2 the fairness criteria is for assigning the time slots to the
3 terminal-side apparatuses in proportion to the number of
4 connections in the terminal-side apparatuses.

1 24. A network-side apparatus as claimed in Claim 17, wherein
2 the fairness criteria is for assigning a part of total time
3 slots equally to the terminal-side apparatuses and then
4 assigning the remaining time slots in proportion to the sum
5 of guaranteed minimum bandwidths for connections in the
6 terminal-side apparatuses.

1 25. A network-side apparatus as claimed in Claim 17, wherein
2 the fairness criteria is for assigning a part of total time
3 slots equally to the terminal-side apparatuses and then
4 assigning the remaining time slots in proportion to the sum
5 of maximum bandwidths for connections in the terminal-side
6 apparatuses.

1 26. A network-side apparatus as claimed in Claim 17, wherein
2 the fairness criteria is for assigning a part of total time
3 slots equally to the terminal-side apparatuses and then
4 assigning the remaining time slots in proportion to the
5 difference between the sum of maximum bandwidths and the sum
6 of guaranteed minimum bandwidths for connections in the
7 terminal-side apparatuses.

1 27. A network-side apparatus as claimed in Claim 17, wherein
2 the fairness criteria is for assigning a part of total time
3 slots equally to the terminal-side apparatuses and then
4 assigning the remaining time slots in proportion to the number
5 of connections in the terminal-side apparatuses.

1 28. A network-side apparatus as claimed in Claim 17, wherein
2 said control means controls, on an equivalent assignment,
3 reassignment of the leftover time slots to the available
4 terminal-side apparatus(es) for reassignment.

1 29. A network-side apparatus as claimed in Claim 17, wherein
2 said control means controls reassignment of the leftover time
3 slots to the available terminal-side apparatus(es) for
4 reassignment, such that the value obtained by subtracting the
5 number of the primarily assigned time slots from the number
6 of the packets stored becomes equal or similar to each other
7 in the available terminal-side apparatus(es) for
8 reassignment.

1 30. A network-side apparatus as claimed in Claim 17, wherein
2 said control means controls reassignment of the leftover time
3 slots to the available terminal-side apparatus(es) for
4 reassignment in proportion to the number of the packets to
5 be transferred.

1 31. A network-side apparatus as claimed in Claim 17, wherein
2 the packet is a cell to be used in an asynchronous transfer
3 mode.

1 32. A network-side apparatus connected to a plurality of
2 terminal-side apparatuses through a shared transmission
3 medium in a packet communication system to assign time slots
4 to the terminal-side apparatuses, the terminal-side apparatus
5 being adapted to transfer one or more packets over the shared
6 transmission medium by using the time slots assigned thereto,
7 each of the terminal-side apparatuses having buffering means
8 for use in storing the packets to be transferred and
9 notification means connected to the buffering means and the
10 network-side apparatus, the notification means being adapted
11 to supply, to the network-side apparatus, information
12 indicative of the number of the packets stored in the buffering
13 means as packets information,
14 the network-side apparatus further comprising:
15 fairness assignment means connected to the terminal-side
16 apparatuses, said fairness assignment means being adapted to

17 assign, in response to the packets information, time slots
18 to the terminal-side apparatuses in accordance with a
19 predetermined fairness criteria, the time slots being assigned
20 as primarily assigned time slots,

21 reassignment control means for use in designating, when
22 one or more leftover time slots are present in at least one
23 terminal-side apparatuses after the assignment of the
24 primarily assigned time slots, the terminal-side
25 apparatus(es) with such leftover time slot(s) as non-available
26 terminal-side apparatus(es) for reassignment and the
27 remaining terminal-side apparatus(es) as available
28 terminal-side apparatus(es) for reassignment, and
29 reassigning the leftover time slot(s) to the available
30 terminal-side apparatus(es) for reassignment,

31 an assignment information management table for managing,
32 for each of the terminal-side apparatuses, packets information
33 corresponding to information indicative of the number of the
34 packets stored in the terminal-side apparatus, the packets
35 information being supplied from the terminal-side apparatus,
36 assigned time slots information corresponding to information
37 indicative of the number of the time slots assigned to the
38 terminal-side apparatus as the number of the primarily assigned
39 time slots, and identifier information indicating whether each
40 of the terminal-side apparatus is available for reassignment
41 or not; and

42 an assigned time slots transmission circuit for use in
43 supplying the assigned time slots information to the
44 terminal-side apparatuses,

45 said fairness assignment means comprising a fairness
46 guarantee assignment circuit for assigning the time slots to
47 all or some of the terminal-side apparatuses in accordance
48 with the fairness criteria at the timing when it is necessary
49 to change assignment of the time slots, to write the number
50 of the primarily assigned time slots into said assignment
51 information management table;

52 said reassignment control means comprising:

53 a reassignment determination circuit for use in obtaining,
54 for each of the terminal-side apparatuses, the assigned time
55 slots information and the packets information by means of
56 looking up said assignment information management table, to
57 compare the number of the primarily assigned time slots and
58 the number of the packets stored for each of the terminal-side
59 apparatuses, said reassignment determination circuit
60 determining to perform reassignment when the number of the
61 primarily assigned time slots exceeds the number of the packets
62 stored for at least one terminal-side apparatus, said
63 reassignment determination circuit determining not to perform
64 reassignment when the number of the primarily assigned time
65 slots is smaller than the number of the packets stored for
66 all terminal-side apparatuses, and in designating the number
67 of the primarily assigned time slots as the number of the time
68 slots assigned to the terminal-side apparatus to send the

69 determined number of the time slots to the assigned time slots
70 transmission circuit;

71 a reassigned terminal-side apparatus determination
72 circuit for use in obtaining, for each of the terminal-side
73 apparatuses, the assigned time slots information and the
74 packets information by means of looking up said assignment
75 information management table when said reassignment
76 determination circuit determines to perform reassignment, and
77 in designating the terminal-side apparatus(es) as available
78 terminal-side apparatus(es) for reassignment where the number
79 of the primarily assigned time slots is smaller than the number
80 of the packets stored and the remaining terminal-side
81 apparatus(es) as non-available terminal-side apparatus(es),
82 to write in said assignment information management table an
83 identifier indicative of availability of the terminal-side
84 apparatus for the reassignment;

85 a reassigned time slots determination circuit for use
86 in obtaining, for the non-available terminal-side
87 apparatus(es), the assigned time slots information and the
88 packets information by means of looking up said assignment
89 information management table, and designating the sum of the
90 differences between the number of the primarily assigned time
91 slots and the number of the packets stored as the number of
92 the leftover time slots to be reassigned, to update said
93 assignment information management table with the number of
94 the packets stored applied to the number of the primarily

95 assigned time slots for the non-available terminal-side
96 apparatus(es); and
97 an efficiency improvement reassignment circuit connected
98 to assigned time slots transmission circuit, said efficiency
99 improvement reassignment circuit for use in:
100 obtaining the packets information for the available
101 terminal-side apparatus(es) for reassignment and the assigned
102 time slots information for all terminal-side apparatuses by
103 means of looking up said assignment information management
104 table, and reassign the number of the leftover time slots to
105 the available terminal-side apparatus(es) for reassignment
106 such that the number of the time slots assigned to the available
107 terminal-side apparatus(es) for reassignment is equal to or
108 smaller than the number of the packets stored, and as a result
109 of this reassignment, if the number of the time slots assigned
110 to the available terminal-side apparatus(es) for reassignment
111 is larger than the number of the packets stored, then
112 designating the available terminal-side apparatus(es) as
113 non-available terminal-side apparatus(es) for reassignment
114 with the number of the packets stored used as the number of
115 the time slots assigned thereto, and reassigning, to the
116 available terminal-side apparatus(es) for reassignment, the
117 difference between the number of the time slots already
118 assigned to the available terminal-side apparatus for
119 reassignment and the number of the packets stored as the number
120 of the leftover time slots, which is repeated until the number
121 of the time slots assigned to the available terminal-side

122 apparatuses becomes equal to or smaller than the number of
123 the packets stored for all available terminal-side apparatuses,
124 and

125 assigning, if no terminal-side apparatus is available
126 for reassignment before completion of the reassignment even
127 though one or more time slots still remain without being
128 assigned, all leftover time slots for reassignment to the
129 terminal-side apparatuses in accordance with the fairness
130 criteria determining, as the number of the time slots assigned
131 to the terminal-side apparatuses, the sum of the number of
132 the primarily assigned time slots obtained from said assignment
133 information management table and the number of the leftover
134 time slots already reassigned, to send the determined number
135 of the time slots to the assigned time slots transmission
136 circuit.

1 33. A method for assigning time slots in a packet communication
2 system comprising a network-side apparatus and a plurality
3 of terminal-side apparatuses connected to the network-side
4 apparatus through a shared transmission medium, the
5 network-side apparatus having control means and being adapted
6 to assign time slots to the terminal-side apparatuses, each
7 of the terminal-side apparatuses having a buffer and being
8 adapted to transfer one or more packets to the shared
9 transmission medium by using the time slots assigned thereto,
10 the method comprising the steps of:

11 supplying, from each of the terminal-side apparatuses,
12 information indicative of the number of the packets stored
13 in the buffer as packets information; and

14 assigning, by the control means in the network-side
15 apparatus, in response to the packets information supplied
16 from each of the terminal-side apparatuses, time slots to the
17 terminal-side apparatuses in accordance with a predetermined
18 fairness criteria, the time slots being assigned as primarily
19 assigned time slots; and

20 controlling, when one or more leftover time slots are
21 present in at least one terminal-side apparatuses after the
22 assignment of the primarily assigned time slots, to designate
23 the terminal-side apparatus(es) with such leftover time
24 slot(s) as non-available terminal-side apparatus(es) for
25 reassignment and the remaining terminal-side apparatus(es)
26 as available terminal-side apparatus(es) for reassignment,
27 and reass the leftover time slot(s) to the available
28 terminal-side apparatus(es) for reassignment.

1 34. A method as claimed in Claim 33, wherein the control means
2 compares the number of the primarily assigned time slots with
3 the number of the packets stored, and designates the number
4 of the primarily assigned time slots as the final number of
5 the time slots assigned to the terminal-side apparatuses when
6 the number of the primarily assigned time slots is smaller
7 than the number of the packets stored for all terminal-side
8 apparatuses.

1 35. A method as claimed in Claim 33, wherein the fairness
2 criteria is for assigning the time slots equally to the
3 terminal-side apparatuses.

1 36. A method as claimed in Claim 33, wherein the fairness
2 criteria is for assigning the time slots to the terminal-side
3 apparatuses in proportion to the sum of guaranteed minimum
4 bandwidths for the connections in the terminal-side
5 apparatuses.

1 37. A method as claimed in Claim 33, wherein the fairness
2 criteria is for assigning the time slots to the terminal-side
3 apparatuses in proportion to the sum of maximum bandwidths
4 for the connections in the terminal-side apparatuses.

1 38. A method as claimed in Claim 33, wherein the fairness
2 criteria is for assigning the time slots to the terminal-side
3 apparatuses in proportion to the difference between the sum
4 of maximum bandwidths and the sum of guaranteed minimum
5 bandwidths for the connections in the terminal-side
6 apparatuses.

1 39. A method as claimed in Claim 33, wherein the fairness
2 criteria is for assigning the time slots to the terminal-side
3 apparatuses in proportion to the number of connections in the
4 terminal-side apparatuses.

1 40. A method as claimed in Claim 33, wherein the fairness
2 criteria is for assigning a part of total time slots equally
3 to the terminal-side apparatuses and then assigning the
4 remaining time slots in proportion to the sum of guaranteed
5 minimum bandwidths for the connections in the terminal-side
6 apparatuses.

1 41. A method as claimed in Claim 33, wherein the fairness
2 criteria is for assigning a part of total time slots equally
3 to the terminal-side apparatuses and then assigning the
4 remaining time slots in proportion to the sum of maximum
5 bandwidths for the connections in the terminal-side
6 apparatuses.

1 42. A method as claimed in Claim 33, wherein the fairness
2 criteria is for assigning a part of total time slots equally
3 to the terminal-side apparatuses and then assigning the
4 remaining time slots in proportion to the difference between
5 the sum of maximum bandwidths and the sum of guaranteed minimum
6 bandwidths for the connections in the terminal-side
7 apparatuses.

1 43. A method as claimed in Claim 33, wherein the fairness
2 criteria is for assigning a part of total time slots equally
3 to the terminal-side apparatuses and then assigning the
4 remaining time slots in proportion to the number of connections
5 in the terminal-side apparatuses.

1 44. A method as claimed in Claim 33, wherein the control means
2 controls, on an equivalent assignment, reassignment of the
3 leftover time slots to the available terminal-side
4 apparatus(es) for reassignment.

1 45. A method as claimed in Claim 33, wherein the control means
2 controls reassignment of the leftover time slots to the
3 available terminal-side apparatus(es) for reassignment, such
4 that the value obtained by subtracting the number of the
5 primarily assigned time slots from the number of the packets
6 stored becomes equal or similar to each other in the available
7 terminal-side apparatus(es) for reassignment.

1 46. A method as claimed in Claim 33, wherein the control means
2 controls reassignment of the leftover time slots to the
3 available terminal-side apparatus(es) for reassignment in
4 proportion to the number of the packets to be transferred.

1 47. A method as claimed in Claim 33, wherein the packet is
2 a cell to be used in an asynchronous transfer mode.

1 48. A method as claimed in Claim 33, wherein the controlling
2 step comprises the steps of
3 designating the sum of the differences between the number
4 of the primarily assigned time slots to the non-available
5 terminal-side apparatus(es) and the number of the packets

6 stored, as the number of the leftover time slots to be
7 reassigned,
8 making the number of the primarily assigned time slots
9 to the non-available terminal-side apparatus(es) for
10 reassignment, be identical to the number of the packets stored,
11 reassigning the leftover time slots to the available
12 terminal-side apparatus(es) such that the number of the time
13 slots to the available terminal-side apparatus(es) does not
14 exceed the number of the packets stored, and
15 if the number of the time slots assigned becomes equal
16 to the number of the packets stored for all available
17 terminal-side apparatuses and at least one leftover time slot
18 remains unassigned,
19 assigning the remaining time slot(s) to all of the
20 terminal-side apparatuses in accordance with the fairness
21 criteria, and
22 using the sum of the primarily assigned time slots and
23 the number of the leftover time slots reassigned, as a final
24 number of the time slots assigned to the corresponding
25 terminal-side apparatus.